(54) Title: METHOD AND APPARATUS FOR SUBJECTING MINERAL PARTICLES TO GAS FLOW

(57) Abstract

Roller grate method and apparatus for simultaneously transporting, agitating and exchanging heat with a bed of solid mineral particles having elongated cylindrical horizontal rollers (15) (15') (15'a) (15'b) with gas passage apertures (32) (32') therethrough; a hopper (17) for feeding mineral particles onto the rollers (15) (15') (15'a) (15'b) and forming a bed (11) having a depth several times greater than the average diameter of the particles; a drive source (not shown) to rotate the rollers (15) (15') (15'a) (15'b) and frictionally engage the cylindrical surfaces with the particles in the lower most layer of the bed and urge the bed along a path of travel transverse to the axis of the rollers (15) (15') (15'a) (15'b); elongated filler members (30) (30') (33) disposed in the nip between adjacent rollers to prevent the particles from jamming the rollers (15) (15') (15'a) (15'b) and to provide resistance to the flow of the bed (11) along said path of travel; and a heat chamber (16) spanning the rollers and a fan (not shown) for forcing a heat transfer gas stream through the gas passage apertures (32) (32') in the rollers (15) (15') (15'a) (15'b) and through the bed (11) as it is being transported, the rollers (15) (15') (15'a) (15'b) and the filler members (30) (30') (33) being adapted to continually agitate the particles and to slowly transport the bed (11) past the gas stream at a velocity which is only a minor fraction of the peripheral velocity of the rollers (15) (15') (15'a) (15'b).
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METHOD AND APPARATUS FOR SUBJECTING MINERAL PARTICLES TO GAS FLOW

This invention relates to method and apparatus for simultaneously transporting, agitating and subjecting solid mineral particles to gas flow, and more particularly to method and apparatus for conveying a deep bed of solid mineral particles at slow velocity while a heat transfer gas is forced through the bed and the particles are continually agitated to increase contact between the solid particles and the gas.

BACKGROUND OF THE INVENTION

Beds of solid mineral particles are often transported during heating or cooling on a horizontal traveling grate comprising parallel grate plates, or grate bars affixed at their ends to endless chains which engage sprocket drive wheels. For example, horizontal traveling grates are used to convey beds of solid mineral particles in limestone, cement and iron ore indurating systems while heating or cooling gas streams are forced through the bed carried on the grate plates. A significant amount of heat energy is wasted as the grate plates and grate chain return. The bed of mineral particles is essentially static as it is transported by the traveling grate, and a relatively high drop exists in the pressure across the bed required to blow the heat transfer gas stream through the bed. Further, relatively high horsepower motors are required to drive the traveling grate chain and the fans which force the gas streams through the bed.

Screens for conveying and sizing material particles such as green taconite pellets are also known which comprise a series of driven, spaced-apart, parallel, screen rods, or rollers, such as disclosed in U.S. patents 2,988,781; 3,438,491 and 3,848,744. The particles are transported in a single layer at a speed
approaching the circumferential velocity of the rollers, the rollers may be of different diameter and driven at different speeds to convey the pellets, the spacing between rollers is varied to classify the pellets according to size, and the rollers may be covered with abrasive resistant rubber, as taught in U.S. patent 3,439,491, or may have a hard chromium outer shell, as taught in U.S. patent 3,848,744, to extend the service life of the rollers. Such conveying and sizing roller screens are not adapted to exchange heat with the pellets and are incapable of transporting a deep bed of pellets at slow velocity while forcing a heat transfer gas stream through the bed.

OBJECTS OF THE INVENTION

Accordingly, it is an object of the invention to provide improved solid mineral particle bed transporting and heat exchange apparatus which eliminates the heat energy lost in prior art traveling grate apparatus as the result of the grate plates and grate chain returning through the atmosphere.

It is a further object of the invention to provide improved method and apparatus for simultaneously transporting and forcing a heat transfer gas stream through a bed of solid mineral particles which increases the heat transfer between the particles and the gas stream in comparison to prior art apparatus.

It is a still further object of the invention to provide improved method and apparatus for conveying and subjecting solid mineral particles to gas flow which continually agitates the particles while they are being conveyed so that all surfaces of the particles are exposed to the gas and the heat transfer between particles and gas is consequently improved in comparison to traveling grate apparatus.

Still another object of the invention is to provide improved method and apparatus for transporting and subjecting solid mineral particles to gas flow which transports a deep bed of the particles at slow speed and
continually agitates the particles to improve the solid-to-gas contact and the heat transfer coefficient in comparison to traveling grate apparatus.

Another object is to provide improved method and apparatus for transporting a deep bed of solid mineral particles at slow velocity while forcing a heat transfer gas stream through the bed and continually agitating the particles wherein the pressure drop and the temperature gradient across the bed are both significantly lower than in prior art apparatus.

A still further object is to provide improved solid mineral particle transporting and heat exchange apparatus which: (1) has lower capital cost and lower maintenance costs than traveling grate apparatus; (2) eliminates the return strand of traveling grate apparatus; and (3) uses particle transporting rollers in certain zones of the apparatus which are of less expensive material than the alloy steel grate plates of traveling grate apparatus.

Still another object of the invention is to provide improved method and apparatus for transporting a deep bed of solid mineral particles at slow velocity and continuously agitating the particles while transferring heat to or from the bed which requires less space for the conveyor apparatus, permits use of lower horsepower drive and fan motors, and requires lower cost to operate such motors than prior art traveling grate apparatus.

**SUMMARY OF THE INVENTION**

In accordance with the method of the invention, solid mineral particles are subjected to gas flow by the steps of delivering the particles onto horizontal apertured cylindrical rollers; forming a bed of the particles on the rollers having a depth several times greater than the average diameter of the particles; continually transferring the particles in the lowermost layer of the bed onto filler bars disposed in the nip between adjacent rollers by rotating the rollers to frictionally engage their cylindrical surfaces with said
particles and thereby agitate the particles and urge the bed in a path of travel transverse to the axes of the rollers; passing a heat transfer gas stream in a generally vertical direction transverse to said path of travel through the apertures in the rollers and through the bed as it is being transported; and controlling the speed of the rollers so that the bed is transported past the gas stream at a relatively slow velocity which is only a minor fraction of the circumferential velocity of the rollers. Some embodiments of the method include the additional step of controlling bed transport speed and/or bed depth by rotating certain downstream rollers at slower speeds than the upstream rollers. The method of the invention includes introducing resistance to the flow of the mineral particle bed by inserting filler bars in the nip between adjacent rollers to thereby transport the bed past the heat transfer gas stream at a relatively slow velocity which is only a minor fraction of the circumferential velocity of the rollers, and certain embodiments include the step of controlling bed transport speed by selectively inserting filler bars of different width between the rollers to thereby vary the magnitude of resistance to bed flow.

Roller grate apparatus in accordance with the invention for slowly conveying solid mineral particles while continually agitating them and subjecting them to gas flow comprises a plurality of parallel horizontal rollers having gas passage apertures therethrough; elongated filler bars disposed in the nip between adjacent rollers with their upper surfaces disposed below the uppermost surfaces of the adjacent rollers; means for delivering the particles onto the rollers and filler bars and for forming a bed of said particles thereon having a depth several times greater than the average diameter of the particles; means to rotate the rollers to thereby frictionally engage their cylindrical surfaces with the bed and continually transfer the particles in the lowermost layer of the bed onto the filler bars and thereby
agitare i particelle e innalzare il letto lungo un percorso parallelo a lungo la direzione longitudinale degli assi dei rulli; il rullo rotante a una velocità angolare più alta del trasporto del letto lungo il percorso. Secondo la configurazione della barra di riempimento e della loro disposizione nel punto di contatto tra i rulli adiacenti, l'influenza del trasporto del letto e la velocità della barra di trasporto del letto e la profondità del letto. In alcuni casi, la barra di riempimento downstream è più larga nella direzione tra i rulli adiacenti per ridurre la velocità del trasporto del letto e/o aumentare la profondità del letto. In altri casi, le aperture dei passaggi del gas sono generalmente aperte in slot circolari sulle superfici cilindriche delle barre di riempimento. I rulli che hanno il minimo tentativo di abrasione sulle particelle contro le barre di riempimento. I particelle minerali solidi sono continuamente scosse dai rulli mentre vengono trasportate in modo che tutte le superfici delle particelle siano esposte alla corrente del gas di trasferimento elettrico, aumentando in questo modo il contatto solido-gas e migliorando il trasferimento di calore tra la corrente del gas e le particelle in confronto a un sistema di trasferimento a vapore e riducendo lo shock e il gradiente termico attraverso il letto.

IN THE DRAWINGS

Fig. 1 is a front view, partially in section, of the drying zone of an indurating system preheater embodying the invention;

Fig. 2 is a partial perspective view of the Fig. 1 embodiment;

Fig. 3 is a cross-section view taken through a plurality of rollers of the Fig. 1 embodiment;
Fig. 4 is a plan view of a roller having circumferential gas passage apertures; Fig. 5 is a cross-section view through the Fig. 4 roller installed in the Fig. 1 apparatus with filler bars of triangular cross-section; Figs. 6 and 7 are schematic views illustrating the positions of the filler bars in the nip between adjacent rollers in different embodiments of the invention; and Fig. 8 is a graph illustrating variation of average bed speed with change in roller speed in an embodiment of the invention similar to Fig. 7. DESCRIPTION OF PREFERRED EMBODIMENTS Referring to the drawings, Fig. 1 shows the drying zone 10 of a roller grate indurating system preheater embodying the invention adapted to simultaneously slowly convey, agitate and transfer heat to a deep bed 11 of discrete solid particles of minerals such as limestone, cement, oil shale or green iron-ore pellets. Preferably the particles are of a size in the range from 3/3 inch to 1-1/2 inch diameter with the size of the largest particles being approximately 3 inch diameter, such limitation being imposed by the time required to conduct heat to the center of the particle. Preheater drying zone 10 includes a plurality of parallel, horizontal, elongated cylindrical rollers 15 mounted for rotation about their longitudinal axes and having gas passage apertures 32 therethrough. Rollers 15 form a roller grate for solid mineral particle bed 11 and are enclosed within an air-tight chamber, or hood 16 which spans the plurality of rollers 15 and typically is approximately 50 feet or more in length. Chamber 16 may have means for delivering the particles onto rollers 15 comprising an inlet hopper 17 for receiving particles such as iron ore pellets from a balling drum and feeding the pellets onto rollers 15, means for forming a bed of the particles on rollers 15 including a transverse internal wall portion 19 adjacent feed hopper 17 which
establishes the bed depth to be several or more times greater than the average diameter of the particles, and a transverse partition 19 providing an outlet 20 through which the heated pellets are discharged to a subsequent heat transfer zone of the indurating system such as a preburn zone. Feed hopper 17 permits the method step of delivering the particles onto the rollers, and transverse wall 18 contributes to the step of forming a bed on the rollers having a depth several times greater than the average diameter of the particles. Preferably rollers 15 are of sufficiently large diameter so that the particles do not engage the uppermost surfaces of adjacent rollers and are not transported at the speed of rollers 15. The grate plates of a traveling grate must be of a material such as high alloy steel that can withstand the hottest indurating system temperature that they move through which, for example, may be in a preburn zone. The material required for rollers 15 is dependent upon the maximum temperature in the heat transfer zone in which they are positioned, i.e., in the drying zone. Inasmuch as rollers 15 in drying zone 10 are not exposed to the hottest temperature for the indurating system, in the same manner as the grate plates of a conventional traveling grate, rollers 15 in drying zone 10 need not be of a high alloy steel, and only approximately 1/3 of the rollers of an iron ore pellet preheater need be constructed of high alloy steel.

A heating gas inlet duct 21 may register with hood 16 and receive hot kiln-off gases from an indurating system kiln (not shown). A motor-driven blowing fan (not shown) communicating with inlet duct 21 may, if desired, in known manner force the heated gases to pass through gas passage apertures 32 and rollers 15 and through mineral particle bed 11 as it is transported. A windbox, or suction box 24 positioned beneath rollers 15 may span the plurality of rollers 15 and collect downdraft heating gases which have passed through the bed 11 on rollers 15. A gas exhaust duct 25 may register with windbox 24, and a
motor-driven suction fan (not shown) may, if desired, be disposed in exhaust duct 25 to suck the heating gases out from windbox 24. It will be apparent that the method step of forcing a gas stream through the gas passage aperture 32 and through the bed is accomplished by hood 16, inlet duct 21, exhaust duct 25, the motor-driven blowing fan within duct 21 and the suction fan within exhaust duct 25.

Cylindrical rollers 15 may be attached to elongated shafts 27 which pass through the sidewalls 28 of hood 16 and are journalled at their ends for rotation about their longitudinal axes in nonfriction bearings 29 outside of the hot zone within hood 16. Suitable seals (not shown) may be provided between shafts 27 and the sidewalls 28 of hood 16, and it will be appreciated that such seals can be simpler than the sealing means required for a traveling grate wherein the grate chains pass through the heat transfer chamber. Each shaft 27 has a sprocket wheel (not shown) attached to one end for engagement with a driving chain (not shown). Drive means for a plurality of rollers are well known such as disclosed in U.S. 3,438,491 and are omitted in order to simplify the description. The drive means for rotating the plurality of rollers 15 at the same speed may include two drive chains, one on each side of hood 16. In alternative embodiments rollers 15 are driven by chains between adjacent rollers, and in still other embodiments certain of rollers 15 are driven at different speeds to control bed transport speed or the depth of bed 11.

Elongated filler bars, or filler members 30, preferably of T-shape cross-section are disposed in the nip between adjacent rollers 15 above their longitudinal axes and are affixed at their ends to sidewalls 28 of hood 16. Filler bars 30 comprise means to prevent the solid mineral particles from entering the gap between adjacent rollers 15, thereby preventing the particles from being crushed between adjacent rollers 15 and also preventing the particles from jamming the rollers 15.
Further, filler bar means 30 provide resistance to the flow of bed 11 along a path of travel transverse to the axes of the rollers 15. The horizontal upper surfaces 33 of the T-shape filler bars 30 are disposed below the uppermost surfaces of the adjacent rollers 15 so that the particles are agitated vertically as they are transferred between rollers and filler bars. The filler bars 30 have maximum resistance to bending when the stem of the T-shape cross-section is disposed vertically and the cross bar thereof is disposed horizontally. In an alternative embodiment represented in Fig. 5 the filler bars 30' are of triangular cross-section.

Filler bars 30 introduce resistance to the flow of bed 11 and permit the bed to be transported past the heat transfer gas stream at a velocity which is only a minor fraction of the peripheral velocity of rollers 15. It will be appreciated that the bed flowrate and bed depth are dependent upon both the width of filler bars 30 and their position relative to the roller longitudinal axes and, further, that by minimizing the width of filler bars 30 the speed of rollers 15 can be decreased to obtain the same bed flowrate or, alternatively, the depth of bed 11 can be increased or its flowrate decreased by increasing the width of filler bars 30.

Rollers 15 together with filler bars 30 form a generally flat surface for mineral particle bed 11 having constantly moving cylindrical portions which frictionally engage the particles in the lowermost layer of the bed and tend to transfer them onto and across filler bars 30 and thereby continually agitate the particles in bed 11 and urge the bed 11 along a path of travel transverse to the longitudinal axes of rollers 15. In typical preheaters the length of hollow rollers 15 may be from 3 to 18 feet, and the roller diameter may vary from 4 to 12 inches depending upon the particular material being conveyed and heated. The rollers 15 deflect slightly under their own weight and the weight of the bed 11, and the minimum diameter of hollow rollers which will not
deflect more than an arbitrary amount, e.g., 1/8 inch, at its center is approximately 6 inches for hollow rollers of 12 foot span, 9 inches for hollow rollers of 15 foot span, and 10 inches for rollers of 18 foot length. The filler bars 30 allow large diameter rollers 15 to be used since the nip angle between adjacent rollers is not of concern.

Rollers 15 of drying zone 10 may be hollow and have a plurality of gas passage apertures 32 therethrough which may be of any desired configuration and are shown in Figs. 1-3 as radially extending slots elongated in a direction parallel to the roller longitudinal axes to permit the heating gas stream to pass vertically through the mineral particle bed 11. In one embodiment using hollow stainless steel rollers 15 of four inch diameter, the total area of the slots 32 in each roller is approximately fifteen percent of the roller surface area, the gap between adjacent rollers 15 is approximately 1/8 inch, the filler bars 30 are 1-1/4 inch wide, and the projected area of the slots 32 and gaps between adjacent rollers 15 is approximately 17 percent of the total surface area formed by rollers 15 and filler bars 30. In such embodiment the width of the filler bars 30 is approximately 31 percent of the diameter of the rollers 15, and preferably the width of filler bars 30 adjacent the upstream end of chamber 16 is the range from 1/5 to 1/2 of the roller diameter. Iron ore pellet beds 11 of up to ten inch depth are conveyed on this embodiment at speeds up to 200 inches per minute with roller speeds in the range of 100 to 150 rpm, and limestone beds of eight inch depth are conveyed at speeds up to 90 inches per minute at roller speeds of 145 rpm with very little degradation of the limestone.

Figs. 4 and 5 illustrate an alternative embodiment particularly suited for conveying green iron ore pellets during heating or cooling in which rollers 15' have gas passage apertures in the form of circumferential, or spiral, slots 32' in the cylindrical roller
surfaces. Breakage of pellets can occur when they are caught between the axially extending slots 32 and the filler bars 30 of the Figs. 1-3 embodiment. In contrast, the circumferential slots 32' of the rollers 15' of the Figs. 4 and 5 embodiment have minimal slot length parallel to filler bars 30 tending to catch and break a pellet and, consequently, pellet breakage is significantly reduced.

As shown in Figs. 4 and 5 each roller 15' preferably comprises a pair of spaced circular steel end plates 39 affixed to a shaft 27 and a plurality of elongated steel bars 36 welded in spaced relation to end plates 39 parallel to the axis of shaft 27 so bars 36 form a cylinder. A stainless steel bar 38 (for example, of 2 millimeter width) is spirally wound on top of and welded to the bars 36 with space between adjacent convolutions to provide the circumferential gas passage slots 32' between adjacent spiral turns of bar 38.

As described hereinbefore, the configuration of filler bars 30 and their position in the nip between adjacent rollers 15 affect the depth of bed 11 and also the bed transport rate, and filler bars 30 preferably have a horizontal upper surface 33 positioned below the uppermost surface of the adjacent rollers 15 so that the particles in the lowermost layer of bed 11 are transferred (due to frictional engagement with the cylindrical surfaces of rollers 15) from rollers 15 onto upper surfaces 33 of filler bars 30 and said particles are thus continually agitated and bed 11 is urged by rollers 15 along the path of travel transverse to the roller axes. In order to achieve relatively slow transport of bed 11 past the heat transfer gas stream, upper surfaces 33 of T-shape filler bars 30 preferably have a width in a direction between rollers in the range between 1/5 to 1/2 the diameters of rollers 15.

Rotation of the rollers at very low speeds to accomplish slow transport of the bed past the heat transfer gas stream has been found unsatisfactory because
the particles jam between the filler bars and the rollers at such low speeds. Fig. 6 illustrates a T-filler bar 30a disposed in the nip between adjacent rollers 15a'-15b' of an embodiment especially adapted for conveying a relatively deep bed of limestone particles and having beveled upstream and downstream longitudinal edges 34 and 35 respectively and wherein upper surface 33 has a width of approximately 1.1875 inches in the direction between adjacent rollers. In the Fig. 6 embodiment, rollers 15a' and 15b' are of 4.75 inch outer diameter and are spaced apart approximately 1/8 inch. Upstream beveled edge 34 of filler bar 30a abuts upstream roller 15a' at a point where the radius of roller 15a' makes an angle of approximately 39° with the horizontal and the tangential frictional force F of roller 15a' on a solid mineral particle in the lowermost layer of bed 11 has a vertically downstream component V tending to move the particle downward onto surface 33 which is approximately 1.2 times greater than the horizontal component H of tangential force F. The greater vertical component V than horizontal component H tends to push T-filler bar 30a downward into the gap between adjacent rollers 15a'-15b' rather than away from upstream roller 15a' since the horizontal component H tends to open a gap between filler bar 30a and upstream roller 15a'. Spring means 36 illustrated schematically resiliently urge filler bar 30a in a downward direction toward rollers 15a'-15b' and thus maintain a minimum gap between the rollers and the filler bars. As the rollers 15a'-15b' rotate, any high spots thereon tend to push the filler bar 30a upward and thus stretch spring means 36 so that the spring force tending to keep the filler bars against the rollers is increased.

Even greater protection against jamming of particles between filler bars and rollers is achieved in the embodiment illustrated in Fig. 7 wherein filler bar 30a is disposed lower in the nip between adjacent rollers 15a'-15b' than in the Fig. 6 embodiment so that the
vertically downward component V of tangential frictional force F on a particle is approximately 3.3 times greater than the horizontal component H. Rollers 15a' and 15b' are spaced with a 1.0 inch gap in the Fig. 7 embodiment, and the upstream beveled edge 34 of filler bar 30a abuts upstream roller 15a' at a point where a radius thereof makes an angle of approximately 17° with the horizontal. The Fig. 7 embodiment was found to operate without jamming of rollers 15a'-15b' even at relatively low roller speeds because the vertically downward component V of the tangential frictional force F acting on the particles tending to push filler bar 30a against roller 15a' is relatively high and the horizontal component H tending to push it away from roller 15a' is relatively low. Both embodiments eliminate jamming of the rollers and result in the desired slow velocity of bed 11, which is only a minor fraction of the circumferential velocity of the rollers, past the gas stream which enters chamber 16 through inlet duct 21 and may be forced through bed 11 by a fan in inlet duct 21 and is exhausted through duct 25.

Because of the configuration of the rollers and the filler bars which effect agitation of the particles, the smaller particles in bed 11 tend to rapidly settle to the bottom of bed 11 after passing over only a few filler bars and rollers so that segregation of particle sizes within bed 11 is rapidly achieved after the particles have been transported only a few feet beyond feed hopper 17.

In some embodiments of the invention, particles at different depths within bed 11 are transported at different speeds along the path of travel. If particles of different color are intentionally disposed in the uppermost and lowermost layers of bed 11, it can be observed in these embodiments that the particles in the uppermost layer are conveyed at approximately 1/2 the velocity of the particles in the lowermost layer.
Resistance to bed flow may be introduced to control bed transport speed or bed depth. In certain embodiments of the invention rollers 15 adjacent outlet 20 from hood 16 are rotated at slower speed than rollers 15 upstream therefrom adjacent feed hopper 17 for the purpose of increasing the depth of bed 11 and/or also for the purpose of slowing down bed transport speed. In other embodiments certain rollers 15 adjacent outlet 20 from hood 16 are stopped for the purpose of increasing the bed depth and/or decreasing bed transport speed. Alternatively, in still other embodiments filler bars 30 are selectively inserted between rollers 15 adjacent outlet 20 which are wider in a direction between rollers than filler bars 30 upstream therefrom for the purpose of increasing resistance to bed flow and thereby increase the depth of bed 11 and/or decrease the bed transport speed. In the embodiments of Figs. 5 and 7, filler bar 30a are of the type utilized adjacent the feed end of the roller grate and are of 1.1875 inch width between 4.75 inch diameter rollers so the ratio of filler bar width to roller diameter is approximately 1-to-4, and in such embodiments filler bars (not shown) may be selectively inserted between rollers 15a'-15b' adjacent outlet 20 from hood 16 having a ratio of filler bar width to roller diameter in the range of from 1-to-3 to 1-to-2 for the purpose of controlling bed depth or bed transport speed.

Fig. 8 is a graph plotting roller speed (as abscissae) versus average velocity of a deep limestone bed (as ordinates) in an embodiment similar to Fig. 7. Curve A shows the material flowrate when the bed is transported at the peripheral velocity of the rollers and illustrates that the flowrate is much too high to effectively heat the limestone particles when the heat transfer gas stream is forced through the bed. Curve B shows the bed flowrate in accordance with the invention when the velocity of bed transport is only a minor fraction of the peripheral velocity of the rollers and
the bed is transported slowly to achieve a high coefficient of heat transfer.

While our invention has been disclosed as embodied in a drying zone 10 of an indurating system preheater, it will be readily apparent that our invention may also be embodied in other material bed conveying and heat exchange apparatus such as preburn and cooling zone indurating apparatus.

Beds of material such as limestone, green iron ore pellets, indurated iron ore pellets, cement and oil shale having a depth greater than several times the average diameter of the mineral particles can be conveyed on the disclosed roller grate material bed conveying and heat exchange apparatus at speeds equal to that typically used on traveling grates and which are only a minor fraction of the circumferential velocity of the rollers. The rotating cylindrical rollers 15 tend to transfer the particles in the lowermost layer of the bed 11 downward onto and across the filler bars 30 and continually agitate the particles and thus produce a dynamic bed in which all surfaces of the particles are exposed to the gas stream, in comparison to known traveling grate systems wherein the bed material remains static on the roller grate plate as the plate is moved. Such dynamic bed increases the solid-to-gas contact, improves heat transfer between material bed particles and the gas stream, and also reduces both the pressure drop and temperature gradient across the bed, in comparison to the static bed transported on prior art traveling grate apparatus.

The following Table 1 compares the pressure drop measured across a bed of indurated pellets being conveyed by apparatus embodying the invention having four inch rollers (termed "roller grate") in comparison to the pressure drop across a similar bed being conveyed by a traveling grate (termed "traveling grate"): 
Table 1

PRESSURE DROP ACROSS BED OF INDURATED PELLETS

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<tr>
<th>BED DEPTH (IN.)</th>
<th>SPEED (RPM)</th>
<th>FLOWRATE (SCFM/FT²)</th>
<th>TEMP. (°F)</th>
<th>DROP PRESSURE (IN. H₂O)</th>
<th>OVER DROP PRESSURE (IN. H₂O)</th>
<th>% DECREASE GRADE ROLLER</th>
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<td>75</td>
<td>0.75</td>
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<td>6</td>
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The following Table 2 compares the heat transfer coefficient measured between the gas stream and beds of material being conveyed by apparatus embodying the invention having four inch rollers (termed "Dynamic Bed") in comparison to the heat transfer coefficient calculated for similar material beds being conveyed by a traveling grate (termed "Static Bed"): 

Table 2

HEAT TRANSFER COEFFICIENT

<table>
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<tr>
<th>MEASURED (DYNAMIC BED) (BTU/HR FT²-°F)</th>
<th>CALCULATED (STATIC BED) (BTU/HR FT²-°F)</th>
<th>AIR FLOWRATE (SCFM/FT²)</th>
<th>BED DEPTH (IN.)</th>
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<td>Fired Iron</td>
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<tr>
<td>Ore Pellets</td>
<td>12.7</td>
<td>9</td>
<td>218</td>
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<tr>
<td>Limestone</td>
<td>13.6</td>
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<tr>
<td>Green Iron</td>
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<tr>
<td>Ore Pellets</td>
<td>31.9</td>
<td>15.8</td>
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</table>

It will be appreciated that the disclosed roller grate solid mineral particle bed conveying and
heat exchange apparatus eliminates the large heat loss which occurs when the grate plates and chain of a typical traveling grate conveyor return through the atmosphere, which heat loss has been measured to be 15 percent of the total energy input in an iron ore pelletizing plant. It will also be appreciated that the rollers of the disclosed solid mineral particle bed conveying and indurating apparatus are not all exposed to the hottest temperature in the same manner that all of the grate plates of a typical traveling grate conveyor are exposed and must be made of material that can withstand the hottest temperature the grate plates will reach, and only approximately 1/3 of the rollers 15 of an iron ore pellet conveying and indurating preheater embodying our invention need be of high alloy steel. Still further, inasmuch as the rollers 15 remain in one position, they are exposed to a constant temperature in comparison to the temperature cycle that the grate plates and chain of a typical traveling grate undergo. Consequently the thermal stress on the rollers 15 is reduced and the life thereof is increased significantly in comparison to the same factors for the plates of a typical traveling grate conveyor.
The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Roller grate apparatus for simultaneously transporting, agitating, and subjecting a bed of discrete solid mineral particles to gas flow comprising, in combination, a plurality of parallel horizontal elongated cylindrical rollers mounted for rotation about their longitudinal axes, elongated filler members disposed in the nip between adjacent rollers, drive means for rotating said rollers, said rollers together with said filler members forming a generally horizontal surface having continually moving portions which are adapted to agitate said particles and transport said bed across said surface in a direction transverse to the longitudinal axes of said rollers at a velocity which is a minor fraction of the circumferential velocity of said rollers, said rollers having gas passage apertures therein which permit a gas stream to pass therethrough in a direction transverse to their longitudinal axes, and means for passing a gas stream in a generally vertical direction through said apertures and said bed while it is being transported and said particles are being agitated.

2. Roller grate apparatus in accordance with claim 1 for exchanging heat with said particles wherein said means for passing a gas stream includes a heat transfer chamber spanning a plurality of said rollers and passes a heat transfer gas through said apertures and said bed while it is being transported.

3. Roller grate apparatus in accordance with claim 1 or 2 and including means for feeding said particles onto said rollers and filler members and for forming a bed of said particles thereon having a depth several times greater than the average diameter of said particles.

4. Roller grate apparatus in accordance with claim 1, 2 or 3 wherein said rollers are of a diameter greater than several times the average diameter of said
particles and said filler members have upper surfaces positioned below the uppermost surfaces of said rollers so that said particles are agitated as they pass across said rollers and said filler members.

5. Roller grate apparatus in accordance with claim 1, 2, 3 or 4 wherein said elongated filler members prevent said particles from jamming said rollers and provide resistance to the flow of said bed in a path of travel transverse to the axes of said rollers, and wherein said rollers frictionally engage said particles in the lowermost layer of said bed and exert tangential forces thereon tending to transfer said particles onto and across said filler members and urge said bed in said path of travel transverse to the axes of said rollers.

6. Roller grate apparatus in accordance with claim 1, 2 or 3 wherein said gas passage apertures are elongated slots extending parallel to the longitudinal roller axes.

7. Roller grate apparatus in accordance with claim 1, 2, 3 or 4 wherein said gas passage apertures comprise generally circumferential slots in the cylindrical roller surfaces.

8. Roller grate apparatus in accordance with claim 1, 2, 3 or 4 wherein said filler members have horizontal upper surfaces whose width in the direction between said adjacent rollers is in the range between 1/2 and 1/5 the diameter of said rollers.

9. Roller grate apparatus in accordance with claim 8 wherein the upstream edge of said horizontal upper surfaces of said filler members abuts the upstream adjacent roller at a point where a force vector tangential of said upstream roller has a vertically downward component that is greater than twice its horizontal component.

10. Roller grate apparatus in accordance with claim 1, 2, 3 or 4 and including spring means for resiliently urging said filler members in a vertically downward direction toward said adjacent rollers.
11. Roller grate apparatus in accordance with claim 1, 2, 3 or 5 wherein certain of said filler members downstream of said feeding means are wider in the direction between adjacent rollers than filler members upstream therefrom to thereby increase the depth of said bed.

12. Roller grate apparatus in accordance with claim 3 or 4 wherein said drive means for rotating said rollers rotates at least one roller downstream from said feeding means at a slower velocity than rollers upstream therefrom to thereby control the depth of said bed.

13. The method of subjecting solid mineral particles to gas flow comprising the steps of:

feeding said particles onto parallel horizontal apertured cylindrical rollers having elongated filler members disposed in the nip between adjacent rollers and forming a bed of said particles on said rollers and said filler members.

rotating said rollers to fractionally engage the cylindrical surfaces thereof with the particles in the lowermost layer of said bed and continually transfer said particles onto and across said filler members to thereby agitate said particles and transport said bed in a path of travel transverse to the axes of said rollers, and

passing a gas stream in a direction transverse to said path of travel through the apertures in said rollers and through said bed as it is being transported, said roller rotating step being at a circumferential velocity substantially higher than the velocity at which said bed is transported along said path of travel.

14. The method of claim 13 wherein said bed forming step forms a bed of said particles having a depth several times greater than the average diameter of said particles.

15. The method of claim 13 or 14 which exchanges heat with said particles and wherein said gas
stream passing step passes a stream of heat transfer gas through said apertures in said rollers and through said bed.

16. The method in accordance with claim 13, 14 or 15 and including the step of segregating said particles in accordance to size while said bed is being transported and said particles are being agitated so that the smaller particles settle by gravity to the lower layers of said bed.

17. The method of claim 13, 14 or 15 and including the step of positioning said filler members at a position in the nip between adjacent rollers wherein the upper surface of the filler members is disposed below the uppermost surfaces of the adjacent rollers to thereby agitate said particles as they are being transported.

18. The method in accordance with any one of claims 13, 14, 15 or 17 and including the step of positioning said filler members at a position in the nip between adjacent rollers where the vertically downward component of the tangential frictional forces of the upstream roller on said particles is greater than twice the horizontal component thereof.

19. The method in accordance with claim 13, 14 or 15 and including the step of controlling the velocity at which said bed is transported by rotating at least one of said rollers downstream from the location of said feeding and bed forming steps at a slower velocity than rollers upstream therefrom.

20. The method in accordance with claims 13, 14 or 15 wherein said filler members introduce resistance to the flow of said bed and including the step of controlling the velocity at which said bed is transported by selectively inserting filler members of different width between adjacent rollers to thereby vary the magnitude of the resistance to flow of said bed introduced by said filler members.
AMENDED CLAIMS
(received by the International Bureau on 3 November 1981 (03.11.81))

1. The method of subjecting solid mineral particles to a heat transfer gas flow comprising the steps of:
   A. feeding said particles onto parallel horizontal apertured cylindrical rollers having elongated filler members disposed in the nip between adjacent rollers and forming a bed of said particles having a depth several times greater than the average diameter of said particles;
   B. supporting said bed on said rollers and said filler members;
   C. rotating said rollers to frictionally engage the cylindrical surfaces thereof with the particles in the lowermost layer of said bed and continually transfer said particles onto and across said filler members to thereby agitate said particles and transport said entire bed in a path of travel transverse to the axes of said rollers;
   D. rotating said rollers in step C at a circumferential velocity substantially higher than the velocity at which said bed is transported along said path of travel; and
   E. passing a stream of heat transfer gas in a direction transverse to said path of travel through the apertures in said rollers and through said bed as it is being transported.

2. The method according to claim 1 characterized by the step of introducing resistance to the flow of said bed to control the velocity at which said bed is transported, by inserting filler members of selected width between adjacent rollers to vary the magnitude of the resistance to flow of said bed introduced by said filler members.

3. The method according to claim 1 or 2 characterized by the step of segregating said particles in accordance to size while said entire bed is being transported and said particles are being agitated so that the
smaller particles settle by gravity to the lower layers of
said bed.

4. The method according to claims 1, 2, or 3
characterized by the step of positioning said filler members
at a position in the nip between adjacent rollers to place
the upper surface of the filler members below the uppermost
surfaces of the adjacent rollers to agitate said particles
as they are being transported.

5. The method according to any one of the claims
1, 2, 3 or 4 characterized by the step of positioning said
filler members at a position in the nip between adjacent
upstream and downstream rollers to cause the vertically
downward component of the tangential frictional forces of
the upstream roller on said particles to be greater than
twice the horizontal component thereof.

6. A roller grate apparatus for performing the
method according to any of the claims 1, 2, 3, 4 or 5
comprising, a plurality of parallel horizontal elongated
cylindrical rollers mounted for rotation about their
longitudinal axes, elongated filler members disposed in the
nip between adjacent rollers and adapted to support a bed of
mineral particles, a feeder for feeding said particles onto
said rollers and filler members and for forming a bed of
said particles thereon having a depth several times greater
than the average diameter of said particles, a drive system
for rotating said rollers at a circumferential velocity
higher than the velocity at which said bed is transported,
said rollers having gas passage apertures therein which
permit a gas stream to pass therethrough in a direction
transverse to their longitudinal axes, and a duct system for
passing a heat transfer gas stream in a generally vertical
direction through said apertures and said bed while it is
being transported and said particles are being agitated.

7. A roller grate apparatus according to claim 6
characterized in that certain of said filler members
downstream of said feeder are wider in the direction between
adjacent rollers than filler members upstream therefrom.
8. A roller grate apparatus according to claim 6 or 7 characterized in that said rollers are of a diameter greater than several times the average diameter of said particles and said filler members have upper surfaces positioned below the uppermost surfaces of said rollers so that said particles are agitated as they pass across said rollers and said filler members.

9. A roller grate apparatus according to claims 6, 7 or 8 characterized in that said rollers frictionally engage said particles in the lowermost layer of said bed and exert tangential forces thereon tending to transfer said particles onto and across said filler members and urge said bed in said path of travel transverse to the axes of said rollers.

10. A roller grate apparatus according to claim 9 characterized in that the upstream edge of said horizontal upper surfaces of said filler members abuts the upstream adjacent roller at a point where a force vector tangential of said upstream roller has a vertically downward component that is greater than twice its horizontal component.

11. A roller grate apparatus according to claims 6, 7, 8, 9 or 10 characterized in that said gas passage apertures are elongated slots extending parallel to the longitudinal roller axes.

12. Roller grate apparatus according to claims 6, 7, 8, 9, or 10 characterized in that said gas passage apertures comprise generally circumferential slots in the cylindrical roller surfaces.

13. A roller grate apparatus according to any of the claims 6 through 12 characterized by a spring device for resiliently urging said filler members in a vertically downward direction toward said adjacent rollers.
EDITORIAL NOTE

The applicant failed to renumber the amended claims in accordance with Section 205 of the Administrative Instructions.

In the absence of any specific indication from the applicant as to the correspondence between original and amended claims, these claims are published as filed and as amended.
# INTERNATIONAL SEARCH REPORT

**International Application No:** PCT/US 81/00371

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)
According to International Patent Classification (IPC) or to both National Classification and IPC

**INT. CL.** F27B 15/00; F26B 3/00, 17/00  
**U.S. CL.** 432/14; 34/33

## II. FIELDS SEARCHED

<table>
<thead>
<tr>
<th>Classification System</th>
<th>Classification Symbols</th>
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<td>U.S.</td>
<td>34/33, 57D, 236, 240</td>
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<td>432/14, 15, 58, 138, 144</td>
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Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

## III. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document, <em>A</em> with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No.</th>
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<tbody>
<tr>
<td><strong>A,E</strong></td>
<td>US, A, 4,258,005 Published 24 March 1981 Ito et al Figures 1, 4, 5, &amp; 6</td>
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  - *A* document defining the general state of the art
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- "T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance

## IV. CERTIFICATION

- **Date of the Actual Completion of the International Search:** 11 August 1981
- **Date of Mailing of this International Search Report:** 21 AUG 1981

ISA/US  

Form PCT/ISA/210 (second sheet) (October 1977)